'Emerging ecosystems' – a washing-stone for ecologists, economists and sociologists?

S.J. Milton*

TWO RECENT WORKSHOPS† HAVE DEBATED the relatively novel concept of the emerging ecosystem. Here I summarize the discussions that took place in the second of the two meetings, held in Brasilia in May this year, and examine its relevance for South Africa and in particular for the arid zone.

A good washing-stone, ideal for pounding the laundry and spreading it to dry, brings people together who might not otherwise have had an opportunity to share information, and to find solutions to the challenges of life. A concept can function as a virtual washing-stone, attracting disciplines that share little in philosophy or approach. One such 'washing-stone' concept is that of 'emerging ecosystems' (EE) dealing with the notion that land, cleared of natural vegetation for agricultural, commercial or industrial use and changed by how it is used, has an uncertain ecological and economic future when management activities cease. Such landscapes are common around the world and in southern Africa. A recent analysis of South African land-cover types[1] found that land transformed by human activities amounts to 21% (25 600 km^2) of South Africa, 51% (15 590 km^2) of Lesotho and 39% (7085 km^2) of Swaziland.

The 'emerging' plant and animal assemblages of transformed landscapes differ from those typical of natural biomes and little is known of their possible ecological trajectories, stability, resilience or costs and benefits to society. The characteristics, evolution and the values to people (in terms of present and future goods and services) of emerging ecosystems with or without mitigation (rehabilitation to return them to some useful ecological or economic function) are likely to vary among biomes and economies.

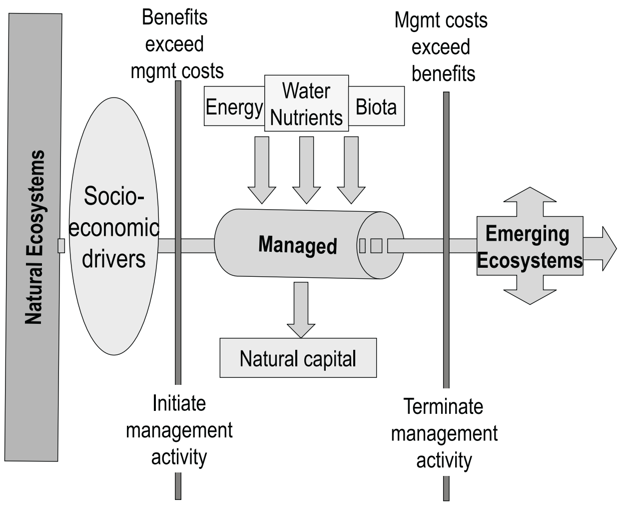
Working definition

An EE was defined at the Granada workshop as 'An ecosystem whose species composition and relative abundance have not previously occurred within a given biome'. At the subsequent multidisciplinary workshop in Brasilia, at least six definitions of EEs were proposed. Some tended to focus on biodiversity issues, while others were more concerned with economic matters and societal responses. As yet no single definition has been agreed on. However, all definitions had in common an initial, often short-lived, anthropogenic driver of persistent biological and physical change and emergence of novel combinations of species. Most definitions mentioned that EEs affected people and economies. A description that incorporates ecological and socio-economic issues in a fairly balanced way is: 'Ecosystems that develop after changing social, economic and cultural conditions so change the environment that new biotic assemblages colonize and persist for decades with positive or negative social, economic and biodiversity consequences'.

Figure 1 illustrates these ideas by showing that socio-economic considerations motivate the use of energy to 'develop' or convert a natural ecosystem to some form of managed land use that brings more immediate benefits to society (liquid assets such as minerals and crops). Management generally involves inputs of energy (in terms of machine time, fertilizer and pesticide, for example)[3] and genetic material, and a loss of 'natural capital' (defined as the renewable and non-renewable resources that occur independently of human action or fabrication[4]).

Such 'resources' include all that nature (genes, individuals, populations, soils, landscapes, waterbodies) has to offer humanity in terms of aesthetic, spiritual, health, utilitarian and other values.

When costs of management exceed benefits, the enterprise becomes economically unsustainable, management ceases and the modified land gradually changes to an emerging ecosystem, the characteristics of which may (or may not) be predicted by ecological theories and notions on succession, alternative stable states, island biogeography, biological invasions, disturbance ecology, niche theory and species–energy theory. According to such ecological theories, biological assemblages that develop on an anthropogenically modified patch (of ground or water) will depend on the composition, quantity and mobility of organisms in the surrounding landscape, the environment, the shape and size of the altered



*Percy FitzPatrick Institute, University of Cape Town, Private Bag, Rondebosch 7701, South Africa.
E-mail sukaroo@mweb.co.za

patch, and interactions among colonizing organisms and between organisms and the new environment.

Interdisciplinary differences in perceptions of emerging ecosystems

Ecologists generally felt that emerging ecosystems were degraded, damaged and in a state that had a reduced value to society. Despite this, many perceived that EEs might provide opportunities for research on the way in which indigenous and introduced microbes, plants and animals colonize and modify novel environments (such as urban industrial sites, toxic mine dumps and sewage ponds) and on ways they might be manipulated to give a better 'product'. On the other hand, sociologists considered that valuation of ecosystems should be made by those parties who actually used or were directly affected by EEs, rather than by academics whose lives were generally unaffected by the systems they were valuing or studying. There was concern that external prejudgement of emerging ecosystems as degraded and in need of rehabilitation could further disadvantage the 'hidden' users, the poor and landless who obtain resources from abandoned land. These stakeholders include people who build informal housing on the land, cut wood, draw water, or gather materials for building, animal feed, or recycling. There was considerable debate as to whether EEs really did have harmful social and economic effects, and, if so, at what scales these were experienced (individual, local, national or global economies).

Examples discussed at the Brasilia workshop

From old tropical forest to new tropical forest. In his introductory talk at the Brasilia workshop, Ariel Lugo (USDA Forest Service) conveyed a positive image of at least some emerging ecosystems. He described his 30-year study of vegetation change in Puerto Rico, an island with a human population density of 450 people per km^2. Within the past century an expanding rural population deforested 95% of the land, only to abandon cultivation in favour of urban livelihoods subsidized by foreign aid and imported petroleum. Within a few decades, trees have returned to 45% of the island's surface, although biomass recovery rate on cleared land was inversely proportional to severity of land use. New forests differ from native forest in that assemblages include alien species, species dominance ratios are higher, old trees and rare species are absent and rates of decomposition have changed. Despite differences between the emerging ecosystem and the original one, Lugo and Helmer[5] argue that control of alien plant species in this wet, tropical environment might not have led to an outcome more favourable for indigenous biota or people

From Cerrado shrubland to unsustainable planted pasture. Carlos A. Klink (Department of Ecology, University of Brasilia), in his introduction to the field trip to 'improved' pastures in Cerrado, envisaged a less advantageous future for altered landscapes. Cerrado, a broad-leaved, sclerophyllous savanna on infertile acid lateritic soil, was Brazil's largest biome, but approximately 30% of this vegetation type has been cleared for the establishment of cattle pastures planted to African grasses. Initially these pastures are very productive, and foreign revenue earned from cattle funded the growth of towns in inland Brazil and boosted the national economy. However, over longer periods the productivity of these planted pastures is unsustainable. Within a couple of decades they are dominated by less palatable grasses which tolerate infertile soil. Grass biomass accumulation increases fire frequency that reduces carbon sequestration. Rooting depths of the introduced grasses (>2 m) exceed those of indigenous species, so that they alter the hydrology, thereby retarding recovery of drought-tolerant shrubs. Klink concluded that - 'development of a modern agriculture in Cerrado has not improved its already uneven social inequality and the environmental costs are high'.[6]

And many more. In breakout groups, workshop participants discussed other examples of emerging ecosystems, usually resulting from unsustainable or inappropriate development. These included 'savannarization' of the Amazon via roads in the rainforest;[7] Chilean mattoral changing to a smog-generating dustbowl via a succession of land uses from cattle, sheep and goat rearing to feral rabbits, wheat growing and finally weeds;[8] and disused shrimp farms that alter estuarine function in former mangrove forests.[9]

Alternative scenarios. For each modified ecosystem, delegates defined a range of alternative scenarios, for example abandonment, various forms of re-development, and rehabilitation. We then attempted to quantify time-frames for change, institutions involved in decision making, stakeholders influenced by decisions, benefits and costs to affected parties and the biodiversity of each pre- and post-development scenario. All groups concurred that, depending on rainfall, temperature, edaphic factors, patch size and the biota in the surrounding matrix, a variety of ecosystems could emerge after a single perturbation. Moreover, the outcome could, at a cost, be manipulated to increase the values of the EE to present or future stakeholders (Fig. 2). It seems likely that restoration to a near-natural state with high natural capital values will be the most costly (energy demanding) option in the short-term (decades), whereas doing nothing is a cheap option that may lead to an EE that produces or conserves little of short- or long-term value. The basis of this assumption is that loss of resources, biodiversity and services from natural ecosystems erodes human welfare in the long term.[10]

Emerging ecosystems in South Africa

Invasion of natural or disturbed ecosystems by alien plants in South Africa is widespread, particularly along waterways. This phenomenon conforms to the draft definition of an EE in that it results in new biotic assemblages that persist for decades with social, economic and biodiversity consequences, which in this case have been well researched. Options for management of invasive alien plants have engaged the involvement and tapped the skills and opinions of government, non-governmental organizations, economists,[11] sociologists, hydrologists, entomologists, ecologists, and a wide range of stakeholders, rich and poor. The outcome has been the nationally and internationally funded Working for Water clearing and rehabilitation programme that seeks to convert multiple problems to multiple opportunities and benefits.[12] It aims to enhance water security, improve the ecological integrity of natural systems and restore the productive potential of land using a community-based, public-works programme and affiliated skills development initiatives that secure economic benefits as a byproduct of alien plants.

Surface mining, or clearing of vegetation and topsoil to remove the minerals, is used in various parts of South Africa to obtain such commonly used materials as limestone, gypsum, gravel, coal, titanium, zirconium and diamonds. Surface mines can be extensive (more than 1000 hectares in extent) and the rate of re-vegetation appears to be related to rainfall, substrate stability and phytotoxicity. Restoring vegetation resembling that pre-mining in structure and composition occurred

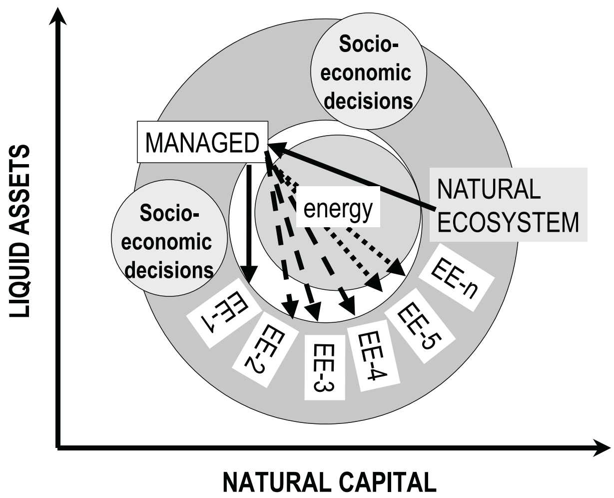


Fig. 2. The decision to invest energy in conversion of natural ecosystems (delivering many services and conserving as yet unexploited tangible and intangible resources) to managed systems, delivering liquid assets (crops, minerals) for consumption and immediate wealth generation is a socio-economic one, made at individual, local or national level. Similarly, the decision to discontinue management (energy investment) is economically driven. However, restoring 'natural capital' also has a cost: decisions on energy investment involve the quality and natural capital value of the ecosystems that emerge after abandonment of commercial management. Various emerging ecosystems (*EE-1* unmitigated to *EE-n* near natural) could develop as a function of different management strategies and levels of energy or economic input. The outer circle indicates the continua among emerging and natural ecosystems, and between people and their environment. The inner circle (energy) is not aligned with the others because some activities (transformation, restoration) require more energy input than others (such as abandonment).

within a decade on the well-watered dunes at Richards Bay, KwaZulu-Natal,[13] but landscaped surface mines in arid Namaqualand appear to remain in an 'emerging' state, saline, dusty and dominated by alien annual weeds[14,15] unless a substantial investment is made in re-vegetation.[16–18] So far, sociologists and economists appear to have engaged less in the debates on appropriate alternative futures for surface mines (see Mentis[19]) than ecologists.

There are many other EEs in South Africa that are likely to be ignored by social scientists and economists alike until their changed function affects the quality of human life at a scale sufficient to force decision-making by local or national government. Some examples of EEs in southern Africa are denuded ostrich camps, over-grazed rangelands dominated by apparently stable populations of toxic or spinescent plants and other forms of dryland degradation,[20,21] disused crop land in semi-arid areas, abandoned plantations of alien trees (eucalypts, pines, wattles) or forage crops such saltbush (*Atriplex nummularia*) or prickly pear (*Opuntia ficus-indica*), drained wetlands, and areas temporally occupied by informal housing, industry or landfills.

Conclusion

The future composition and function of anthropogenically altered ecosystems is for society to decide. Such a decision should ideally consider a wide range of present and future stakeholders and a multidisciplinary analysis of the costs and benefits of options ranging from neglect though re-allocation to rehabilitation and restoration. If society decides to do nothing, new ecosystems will gradually emerge. If society decides to manage the emergence, it is possible that social, economic and ecological values may be enhanced. However, the likelihood of governments allocating resources to intervene in emerging ecosystems will depend on awareness of the EE phenomenon and on the availability of social, economic and ecological analyses of alternative scenarios. As yet there has been little research into the characteristics of ecosystems that emerge from large-scale or prolonged anthropogenic use. The assumptions that EEs are species-poor, dysfunctional, dominated by alien species and a liability to humanity may need to be tested, and testing the EE concept will provide a washing-stone over which ecologists, economists and sociologists can meet to share and compare their visions of the future.

Suggestions from James Aronson and a reviewer improved this paper. The author's participation in the workshop was facilitated by UNESCO.

1. Fairbanks D.H.K, Thompson M.W., Vink D.E., Newby T.S., van den Berg H.M. and Everard D.A. (2000). The South African land-cover characteristics database: a synopsis of the landscape. *S. Afr. J. Sci.* **96**, 69–82.
2. Arico S. and Douglas I. (2003). Unpublished report of discussions at the UNESCO/MAB-SCOPE-University of Brasilia Workshop on Socio-economic Aspects of Emerging Ecosystems (Brasilia, 4–7 May 2003), availale from http://www.unesco.org/mab/EE/forum.htm
3. Tharakan P.J., Kroeger T. and Hall C.A.S. (2001). Twenty years of industrial development: a study of resource use rates and macro-efficiency indicators for five Asian countries. *Environ. Sci. Policy* **4**, 319–332.
4. Costanza R. and Daly H.E. (1992). Natural capital and sustainable development. *Cons. Biol.* **6**, 37–46.
5. Lugo A.E. and Helmer E. (2002). Puerto Rico's new forests. Abstracts of studies from participants of the Granada Workshop. Available from http://www.unesco.org/mab/cooperation/scope/sopeabs.htm (accessed on 4 April 2003).
6. Klink C.A. (2002). Human occupation and land-use of Brazil's tropical savannas (the Cerrado). Abstracts of studies from participants of the Granada Workshop. Available from http://www.unesco.org/mab/cooperation/scope/sopeabs.htm (accessed on 4 April 2003).
7. Nepstad D., Capobianco J.P., Barros A.C., Carvalho G., Moutinho P., Lopes U. and Lefebvre P. (2002). *Roads in the rainforest: environmental costs for the Amazon* 'future scenarios of the Amazon' project report. Amazon Environmental Research Institute and Instituto Socioambiental, Brazil.
8. Jaksic F.M. (1998). Vertebrate invaders and their ecological impacts in Chile. *Biodiv. Conserv.* **7**, 1427–1445.
9. Stevenson N.J. (1997). Disused shrimp ponds: options for redevelopment of mangrove. *Coastal Mngmnt* **25**, 423–425.
10. Balmford A., Bruner A., Cooper P., Costanza R., Farber S., Green R.E., Jenkins M., Jefferiss P., Jessamy V., Madden J., Munro K., Myers N., Naeem S., Paavola J., Rayment M., Rosendo S., Roughgarden J., Trumper K. and Turner R.K. (2002). Economic reasons for conserving wild nature. *Science* **297**, 950–953.
11. Turpie J.K. and Heydenrych B.H. (2000). Economic consequences of alien infestation of the Cape Floral Kingdom's fynbos vegetation. In *The Economics of Biological Invasions*, eds C. Perrings, M. Williamson and S.Dalmazzone, pp. 214–261. Edward Elgar, Cheltenham, Glos.
12. Van Wilgen B.W., Marais C., Magadlela D., Jezile N. and Stevens D. (2002). Win-win-win: South Africa's Working for Water programme. In *Mainstreaming Biodiversity in Development — case studies from South Africa*, eds S.M. Pierce, R.M. Cowling, T. Sandwith and K. MacKinniin, pp. 5–20. The World Bank, Washington, D.C.
13. Mentis M.T. and Ellery W.N. (1998). Environmental effects of mining coastal dunes: conjectures and refutations. *S. Afr. J. Sci.* **94**, 215–222.
14. Desmet P.G. (1996). *The vegetation and restoration potential of the coastal belt between Port Nolloth and Alexander Bay, Namaqualand, South Africa.* M.Sc. thesis, University of Cape Town.
15. Schmidt A. (2002). *Strip-mine rehabilitation in Namaqualand.* M.Sc. thesis, University of Stellenbosch.
16. Lubke R.A. and Avis A.M. (1998). A review of the concepts and application of rehabilitation following heavy mineral dune mining. *Mar. Pollut. Bull.* **37**, 546–557.
17. Burke A. (2001). Determining landscape function and ecosystem dynamics to contribute to ecological restoration in the southern Namib Desert. *Ambio* **30**, 29–36.
18. Mahood K. (2003). *Strip mining rehabilitation by translocation in arid coastal Namaqualand, South Africa.* M.Sc. thesis, University of Stellenbosch.
19. Mentis M.T. (1999). Diagnosis of the rehabilitation of opencast coal mines on the Highveld of South Africa. *S. Afr. J. Sci.* **95**, 210–215.
20. Hoffman M.T. and Ashwell A. (2001). *Nature Divided — land degradation in South Africa.* University of Cape Town Press, Cape Town.
21. Kerley G.I.H., Knight M.H., De Kock M. (1995). Desertification of subtropical thicket in the eastern Cape, South Africa: are there alternatives *Environ. Monitor. Assess.* **37**, 211–230.